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Effect of Different Cropping Systems on Distribution of DTPA-Extractable and Total Zn, Cu, Fe and Mn Fraction in Alluvial Soils of Punjab

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Abstract

A field experiment was in progress since 2000. The objective of the investigation was to study the long term effect of different cropping systems on physico-chemical properties of soil and distribution of DTPA and total Zn, Cu, Fe and Mn after 8 years of continuous cropping. The experiment comprised ten treatments combinations. Among different cropping systems, toria, gobhi sarson, groundnut were included to increase the influx of DTPA and total Zn, Cu, Fe and Mn fractions. Besides improvement in DTPA-extractable Zn, Cu, Fe and Mn content, these crops showed significant improvement in the soil nutrient status with the addition of biomass by toria, gobhi sarson, groundnut and cotton crops. Rice-wheat system reported the highest content of DTPA-Zn (5.86 mg/kg), Fe (13.96 mg/kg) and Mn (5.08 mg/kg) followed by maize-wheat, maize-wheat-summer mungbean, maize-potato-summer mungbean and maize-potato-onion cropping systems. Sarson based cropping systems viz. cotton-African sarson, cotton-gobhi sarson transplanted and summer groundnut-toria + gobhi sarson reported the highest content of DTPA-Zn, Fe and Mn followed by groundnut-potato-pearlmillet system. Our results evinced that sarson and groundnut based cropping systems reported the higher content of total Zn, Cu, Fe and Mn indicating that total fractions of micronutrients can be transferred to their corresponding readily available forms. The results of our study further reported that the inclusion of cotton, gobhi sarson, african sarson, toria and groundnut in the cropping systems could help in mobilization of DTPA Zn, Cu, Fe and Mn and build their concentrations in the soil to sustain the agricultural systems.
Key words : Different cropping systems, DTPA, Total Zn, Cu, Fe and Mn, Physico-chemical properties.

Rice-wheat, maize-wheat and cotton-wheat are three predominant cropping systems, being practiced by majority of farmers in different agro-climatic zones of Punjab. Approximately 10.5 million ha under this cropping system contributes about 75% of total food grain production (203 million tons) in India. About 33% of India's rice and 42% of wheat is grown in this system, consuming nearly 65% of total fertilizers to maintain the yield levels which they were getting a few years back (1). The production of food grains is increasing year after year due to intensive cultivation thereby depleting a huge amount of macronurients along with Zn, Fe and Mn. The availability of Zn, Fe and Mn is higher in soil when pH range is slightly acidic to neutral (2). Ismail et al. (3) reported that among the six cropping systems sorghum-pigeonpea increased the content (mg/kg) of DTPA extractable Zn (1.12), Fe (5.39) and Mn (18.21). Sangwan and Singh (4) reported that alkaline soils reduced the distribution of Mn and Fe. Elbordiny et al. (5) observed that Zn, Fe and Mn were positively correlated with slightly acidic pH, OM, CEC and clay content but negatively correlated with $CaCO_3$ and gypsum contents in the different soil layers in salt effected soils. Dhane and Shukla (6) observed the relationship of Zn, Fe and Mn with some soil properties like OC and clay contents and reported that Zn, Fe and Mn were positively correlated with OC and clay content in soils. Tiwana and Narang (7) reported that incorporation of rice and wheat residues in rice-wheat cropping system increased the status of Zn, Fe and Mn in soil. Balloli et al. (8) reported that the continuous practicing of rice-wheat cropping system resulted in buildup of DTPA-extractable Zn, Fe and Mn. Agbenin (9) showed that the distribution of Fe depends on the distribution of clay in the soil profile but the distribution of Mn does not depend on the clay movement in soil on long-term rice-wheat experiment. Maskina et

Table 1. Different cropping systems adopted in the experiment.

Treat-ments	Cropping System	*Kharif*	*Rabi*	Summer
T_1	Rice-Wheat	Rice	Wheat	–
T_2	Maize-Wheat	Maize	Wheat	–
T_3	Maize-Wheat-Mungbean	Maize	Wheat	Mungbean
T_4	Maize-Potato-Mungbean	Maize	Potato	Mungbean
T_5	Maize-Potato-Onion	Maize	Potato	Onion
T_6	Cotton-Wheat	Cotton	Wheat	–
T_7	Cotton-African sarson	Cotton	African sarson	Cotton
T_8	Cotton-Gobhi sarson (T)	Cotton	Gobhi sarson (T)	–
T_9	G. nut-Toria + Gobhi sarson	Groundnut	Toria + Gobhi sarson	–
T_{10}	G. nut-Potato-Bajra (F)	Groundnut	Potato	Bajra (F)

al. (10) observed an increase in DTPA extractable Zn and Fe with addition of FYM in soil in rice-wheat rotation whereas, depletion in available Zn, Fe and Mn content with continuous cropping of rice-wheat-cowpea system was observed by Kumar and Yadav (11). Green manuring and soil applied Mn to rice-wheat system increased the DTPA-extractable Mn which is attributed to reduction in pH and submergence (12). Kher (13) in maize-wheat cropping system reported the decreasing trend of available Zn, Fe and Mn in the profile. The vertical distribution of Zn, Fe and Mn was observed by Verma et al. (14, 15) in different soil profiles in central Punjab, reported higher content of Zn, Fe and Mn in fine textured soils of old flood plain and lower content in sandy soils. In maize-wheat cropping system, Setia and Sharma (16) reported that increase in the level of N alone or in combination with K depleted the available Zn, Fe and Mn content and increased the Fe and Zn content of the with increasing the level of P.

Agbenin (9) reported the changes in DTPA-Fe and Mn fractions to a greater extent in a savanna Alifisol cultivated for 50 years and fertilized with NPK, FYM and FYM+NPK in the experimental field. Sekhon et al. (17) observed that application of organic manurs resulted in the increase in DTPA-Zn, Cu, and Fe and Mn fractions. Similarly FYM reduced the concentration of residual micronutrients and increased the DTPA fraction of micronutrients. Saha and Mandal (18) showed that more than 85% of applied Cu was distributed in DTPA fractions. Submergence during the rice growth period caused decrease in DTPA micronutrients. Herencia et al. (19) showed the percentage of DTPA-Zn, Cu, Fe and Mn are in the order of Mn>Zn>Cu>Fe and also showed that adition of OM caused Zn and Fe to move from less soluble forms to more plant available (DTPA) forms. Iu et al. (20) and Mitra and Mandal (21) reported the increase in DTPA micronutrient fractions which could be attributed to the decrease of this form held on the inorganic sites and bound on the oxide surfaces with the incorporation of GM. Gajendragadkar and Rathore (22) and Hannam and Ohki (23) reported similar results in Entisols. Madal et al. (24) observed that addition of 0.5% organic matter caused a substantial increase in the contents of DTPA. Hellal (25) reported from his green house pot experiment that addition of composted mixtures increased water soluble plus exchangeable iron in soil, as a result of application of composted mixture. Behera and Singh (26) reported the data regarding DTPA-Zn, Cu, Fe and Mn in soil before sowing of maize and after harvest of wheat during cropping 32 cycle of maize-wheat system. They further observed that DTPA-Zn content varied from 1.05 to 2.16 mg/kg before sowing of maize and 1.18 to 2.08 mg/kg after harvest of wheat under various treatments. The highest value was recorded under 100% NPK + Zn at both stages. The DTPA-soil Fe, Mn and Cu under different treatments ranged from 5.71 to 6.78, 1.01 to 18.78 and 1.46 to 1.60 mg/kg respectively before sowing of maize and from 5.57 to 6.58, 1.08 to 19.85 and 2.01 to 2.10 mg/kg respectively after harvest of wheat. Kopec and Przetaczek (27) showed comparison of DTPA extractable metals in the year 3 and in the year 37 of the experiment it was found that these contents were decreased in the year 37 in case of Zn by 8.5—46.6%, for Mn by 57.2—74.1% and in Fe it was higher by 23—59%. The content of Cu was

Table 2. Initial physico-chemical properties of the experimental soil at the start of the experiment.

	Physico-chemical properties	Value
1	Texture	Loamy sand
2	pH (1:2 :: Soil : solution ratio)	7.20
3	EC (dS/m)	0.40
4	Organic carbon (%)	0.383
5	Available nitrogen (kg/ha)	71.7
6	Available phosphorus (kg/ha)	41.4
7	Available potassium (kg/ha)	89.6

increased by 10—136% in the year 37 than in the year 3 of experiment.

Agbenin and Henningsen (28) reported distribution of total Zn, Cu, Fe and Mn fractions and their contribution towards availability and plant uptake of micronutrients under long-term maize-wheat cropping sequence indicated residual micronutrients as the dominant portion of total Zn, Cu, Fe and Mn. Similar results were reported by Behera et al. (29, 30) who reported the distribution of total-Zn fractions and their contribution towards availability and plant uptake of zinc under long-term maize-wheat cropping in an inceptisol. However, Sharma et al. (31) reported the decrease total fraction with GM after the harvest of wheat which could be due to an increase in the DTPA fractions and held on inorganic sites. Sharma and Bapat (32) reported similar results. In the soil environment, the micronutrients are present in different forms and they transfer from one form to other under different cropping sequences (33).

The inclusion of toria, gobhi sarson, groundnut, moongbean, cotton and short other duration leguminous crops in major cropping systems may ameliorate micronutrient deficiencies to some extent as these crops have been found to increase the mobilization of micronutrients in soil. Multiple cropping systems have been gaining greater advocation in the present day farming and this imposes a heavier burden on the soil health, not only by the number of crops it has to support in a given period but also by the quantum of fertilizers applied. Rice and wheat are dominant components of Indian food security system as it is consumed as major staple food. Presently, rice-wheat cropping system in the Indo-Gangetic plains is showing sign of fatigue due to continuous cropping of highly nutrient and water exhaustive cereal-cereal system for the last three decades and needs its replacement with other cropping systems which can yield better and sustain soil health. The information pertaining to nutrient cycling and their transformation under different cropping systems is lacking which needs further investigation. Keeping in view these points, the present research was conducted to study the transformation and distribution of DTPA-extractable and total Zn, Cu, Fe and Mn in soils under different cropping sequences and to identify the cropping sequences which may help in mobilization of more Zn, Cu, Fe and Mn content in soil for the fast amelioration of their deficiency.

Methods

Location of the Experimental Site

The field experiment with ten cropping systems was in progress since *kharif* of 2000 in the Research Farm, Department of Agronomy, Punjab Agricultural University Ludhiana. The experimental field lies in the central zone of Punjab situated at 30^0 56′ N latitude and $75^0$52′E longitude with a mean elevation of 247 m above mean sea level. The experiment comprised ten treatment combinations as given in Table 1.

Weather Parameters of Experimental Site

Ludhiana has hot moist, semi-arid with alluvial, medium available water holding capacity. This climate zone (Zone-4) of Ludhiana is classified under hot moist and semi-arid sub-tropical class. The mean values of minimum and maximum temperature recorded in 2008 during growing season of rice and wheat ranged from 27.1—34.1 C and 8.6—27.6 C respectively. The value of mean minimum to maximum relative humidity during growing season of rice and wheat ranged from 69—89 and 38—95% respectively. The average sunshine hours during growing season of wheat ranged from 5.1—6.1 hours/day. The cumulative rainfall ranged from 152.7—392.8 mm and 0.4—13.9 mm during growing season of rice and wheat respectively.

Ten cropping systems were evaluated for their physico-chemical properties, DTPA and total Zn, Cu, Fe and Mn fractions viz., T_1—Rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.), T_2—Maize (*Zea mays*

Table 3. Distribution of basic parameters and macronutrients in different cropping systems.

Treat-ments	Cropping systems	Texture	Basic parameters pH	EC (dS^{-1})	OC (%)	Macronutrients N	P	K
T_1	Rice-Wheat	ls	7.43	0.31	0.42	225.8	32.9	134.9
T_2	Maize-Wheat	ls	7.42	0.28	0.45	235.6	45.8	149.5
T_3	Maize-Wheat-Mungbean	sl	7.65	0.32	0.48	242.8	49.5	145.3
T_4	Maize-Potato-Mungbean	sl	7.29	0.31	0.47	264.5	50.6	160.5
T_5	Maize-Potato-Onion	sl	7.40	0.31	0.53	262.7	50.8	132.5
T_6	Cotton-Wheat	ls	7.58	0.34	0.46	256.8	45.6	138.4
T_7	Cotton-African sarson	sl	7.66	0.30	0.48	254.6	45.4	135.4
T_8	Cotton-Gobhi sarson (T)	sl	7.56	0.32	0.49	253.8	46.5	135.6
T_9	G.nut-Toria + Gobhi sarson	ls	7.96	0.34	0.48	240.3	43.9	137.5
T_{10}	G. nut-Potato-Bajra (F)	ls	7.42	0.35	0.54	243.8	45.6	142.8
	Average	–	7.53	0.32	0.49	248.1	45.7	141.2
	CD (0.5)	–	NS	NS	0.04	4.65	2.32	12.96

L.)-wheat, T_3—Maize-wheat-summer mungbean (*Vigna radiata* L), T_4—Maize-potato (*Solanum tuberosum* L.)-Summer mungbean, T_5—Maize-potato-onion (*Allium cepa* L.), T_6—cotton (*Gossypium hirsutum* L.)-wheat, T_7—Cotton-African sarson (*Brassica carinata A.*), T_8—Cotton-gobhi sarson transplanted (*Brassica napus* sub-sp. *oleifera* var *annua*), T_9—Summer groundnut (*Arachis hypogaea* L.)-toria (*Brassica rapa var toria*) + gobhi sarson and T_{10}—Summer groundnut-potato-pearlmillet (*Pennisetum glaucum* L.). A randomized block design was followed with four replications.

Forty soil samples were collected from 0—15 cm soil layer from all the replications after harvesting of *kharif* season crop in October 2008. The soil samples were analyzed in the laboratory using standard procedures. The soil texture was determined by method designed by Day (34). The electical conductivity (EC) was determined with method of Richard (35). Rapid titration method (wet digestion method) was used for organic carbon determination (36). Available nitrogen, phosphorus and potassium were determined by the methods described by Subbiah and Asija (37), Olsen et al. (38) and Merwin and Peech (39) respectively.

The initial physico-chemical properties of experimental soil as determined on 2000 were reported in Table 2. The soil of the experimental field was Tolewal loamy sand soil (*Typic Ustochrept*) with, EC 0.40 dS/m, natural pH 7.20, low in organic carbon (0.38%), low in available N (71.7 kg/ha), high in P (41.4 kg/ha) and low in K (89.6 kg/ha).

DTPA-Zn, Cu, Fe and Mn Fractions

Micronutrients cations (Zn, Cu, Fe and Mn) were determined from 1 : 2 soil-extractant ratio using DTPA-TEA buffer (0.005 M DTPA + 0.001 M CaCl2 + 0.1 M TEA, pH 7.3) and concentration of these micronutrients was measured on an atomic absorption spectrophotometer (FS-AAS). Availability of Zn, Cu, Fe and Mn was assessed by extracting 10 gm portion of soil sample with 20 ml of diethylenetriamine penta-acetic acid (DTPA) as described by Lindsay and Norvell (40).

Total Zn, Cu, Fe and Mn Fractions

For total elemental analysis of Zn, Cu, Fe and Mn, a 0.5 gm sample of soil was digested with 5 ml of hydrofluoric acid (HF), 1.0 ml of perchloric acid (HClO4) and 5—6 drops of nitric acid (HNO3) in a 30 ml capacity platinum crucibles (41). When the soil became completely dry in the crucible the residue in the crucible was completely dissolved in 5 ml of 6N HCl. The contents of the crucible were transferred to 100 ml volumetric flask with double distilled water. After proper dilution with double distilled water the digests were analyzed for total Zn, Cu, Fe and Mn by using an atomic absorption spectrophotometer (FS-AAS).

Statistical Analysis of Data

The experiment was laid out in a randomized block design with four replications. The experimental data was analyzed using procedure given by Panse and Sukhamte (42).

Table 4. Distribution of DTPA-extractable micronutrients in different cropping systems.

Treat-ments	Different cropping systems	DTPA-extractable micronutrients (mg/kg)			
		Zn	Cu	Fe	Mn
T_1	Rice-Wheat	6.86	0.36	13.96	7.08
T_2	Maize-Wheat	4.65	0.38	9.62	4.62
T_3	Maize-Wheat-Mungbean	5.38	0.34	11.36	5.42
T_4	Maize-Potato-Mungbean	5.42	0.47	11.56	5.60
T_5	Maize-Potato-Onion	4.02	0.43	5.64	4.62
T_6	Cotton-Wheat	4.20	0.46	6.78	4.34
T_7	Cotton-African sarson	5.98	0.40	7.74	5.98
T_8	Cotton-Gobhi sarson (T)	5.76	0.48	7.40	5.76
T_9	G. nut-Toria+Gobhi sarson	3.98	0.35	5.24	4.46
T_{10}	G. nut-Potato-Bajra (F)	4.35	0.36	5.18	4.50
	Average	5.06	0.40	8.45	5.24
	CD (0.5)	0.19	0.07	0.12	0.08

Results and Discussion

Available NPK and Organic Carbon Distribution in Different Cropping Systems

The data regarding distribution of pH, EC, texture, OC, available N, P and K in the different cropping systems is presented in Table 3. The texture of these systems varied from loamy sand to sandy loam. The pH of the soils under different systems varied from 7.29—7.96. As compared to rice-wheat system (T_1) EC reported higher content in surface soils in T_6, T_9 and T_{10} cropping systems. Similalarly higher values of OC were observed in T_4 and T_{10} cropping systems as compared to rice-wheat system which is associated with addition of biomass through leaf litter, root biomass of *mungbean and bajra fodder.* The low content of OC in rice-wheat (T_1) and maize-wheat (T_2) cropping systems implies that these systems are nutrient exhaustive systems which deplete OC from the soil system. Low level of available N was reported in rice-wheat system whereas, all the other cropping systems reported higher a level of available N, showing that rice-wheat is a nutrient exhaustive cropping system. The data clearly indicated that *mungbean*, onion and potato based cropping systems can restore soil nutrient status especially by maintaining its OC, EC, available N, P and K levels whereas rice-wheat system failed to achieve its nutrient status to its sustainable level with its long run cultivation.

In all the ten cropping systems, pH, EC, OC, available N, P and K content varied from 7.19 to 7.66, 0.28 to 0.35 dS/m, 0.42 to 0.54%, 225.8 to 262 kg/ha, 32.9 to 50.8 kg/ha and 134.9 to 160.5 kg/ha with mean of 7.53, 0.32 dS.m, 0.49%, 248.1 kg/ha, 45.7 kg/ha and 141.21 kg/ha respectively (Table 3). Both pH and EC didn't show any significant effect with cropping systems whereas, OC, available N, P and K reported increase in their content with different cropping systems. Jiang et al. (43, 44) reported that pH, EC, and available N, P and K in the profile were associated with the organic carbon. Similar results were reported by Aluko and Fagbenro (45) the similar results on the role of tree species and land use systems in organic matter and nutrient availability in degraded Ultisol of Southeastern Nigeria. Sharma et al. (31) reported the decrease in pH and increase in OC in the profile was associated with the increase available P and K.

DTPA-Extractable Zn, Cu, Fe and Mn in Different Cropping Systems

The data pertaining to DTPA-Zn, Cu, Fe and Mn is presented in Table 4. The DTPA-Zn in different cropping systems reported irregular trend with but higher level of DTPA-Zn (6.86 mg/k) was reported in rice-wheat system. Similarly DTPA-Fe and Mn reported the same trend as that of Zn but its content is reportedly higher in case of rice-wheat system (13.96 mg/kg Fe and 7.08 mg/kg Mn). The higher content of DTPA-Zn in rice-wheat system as compared with other cropping systems which was associated with application of Zn (62.5 kg/ha $ZnSO_4.7H_2O$ annually fertilizer to rice-wheat system whereas, the higher content of DTPA-Fe and Mn in rice-wheat system was attributed to reduction of these ions (Fe^{+2} and Mn^{+2}) during rice cultivation. In all the ten cropping systems, DTPA-extractable Zn, Cu, Fe and Mn content varied from 4.02 to 6.86 mg/kg, 0.35 to 0.48 mg/kg, 15.18 to 13.96 mg/kg and 4.34 to 7.08 mg/kh with mean of 5.06 mg/kg, 0.40 mg/kg, 8.45 mg/kg and 5.24 mg/kg (Table 4). Among these different cropping systems, cotton based cropping systems (T_7 and T_8) except T_6 reported higher content of DTPA-Zn, Fe and Mn. Also the inclusion of mungbean (T_3 and T_4) in the main cropping systems reported higher content of DTPA-Zn, Fe and Mn. Groundnut based cropping systems didn't help in mobilization of more DTPA-Zn, Fe and Mn

Table 5. Distribution of total micronutrients in different cropping system.

Treat-ment	Different cropping systems	Total micronutrient (mg/kg) Zn	Cu	Mn	Fe (%)
T_1	Rice-Wheat	28.6	2.5	243.5	1.36
T_2	Maize-Wheat	27.0	3.6	252.5	1.22
T_3	Maize-Wheat-Mungbean	28.0	1.5	266.0	1.52
T_4	Maize-Potato-Mungbean	26.5	1.4	279.5	1.50
T_5	Maize-Potato-Onion	26.5	1.8	254.0	1.52
T_6	Cotton-Wheat	30.0	2.6	286.0	1.68
T_7	Cotton-African sarson	32.0	1.8	287.0	1.74
T_8	Cotton-Gobhi sarson (T)	33.5	1.8	277.5	1.55
T_9	G. nut-Toria+Gobhi sarson	38.0	1.6	292.0	1.86
T_{10}	G. nut-Potato-Bajra (F)	33.0	1.8	282.4	1.42
	Average	30.31	2.04	272.04	1.54
	CD (0.5)	1.29	0.45	5.12	NS

content in the soil. Interestingly the contents of DTPA-Zn, Cu, Fe and Mn were reported by groundnut-potato-bajra (fodder) in T_{10} showing that bajra fodder depletes the DTPA-Zn, Fe and Mn level. Verma (15) observed similar pedopheric variations in distribution of DTPA micronutrients in soils developed on different physiographic units in central parts of Punjab, India. Kopec and Przetaczek (27) showed comparison of DTPA extractable metals in the year 3 and in the year 37 of the experiment and it was found that their contents decreased in the year 37 in Zn by 8.5—46.6%, Mn by 57.2—74.1% and Fe by 23—59%. The content of Cu was increased by 10—13% in the year 37 than in the year 3 of experiment. Dhaliwal (12) reported that different chemical pools of Mn as influenced by submergence, green manure and soil applied Mn under rice-wheat system and observed that DTPA-Mn increased with submergence and green manure application. Dhane and Shukla (6) reported similar distribution of DTPA-extractable Zn, Cu, Mn and Fe is some soil series of Maharashtra. Elbordiny and Camilia (11), Gupta and Mehla (46) reported same results of DTPA-Zn, Cu, Fe and Mn in rice-wheat rotation. Ismail et al. (3) in a impact of nutrient management practices on sorghum based cropping systems on micronutrient dynamics in Vertisols reported same results of DTPA-Zn, Cu, Fe and Mn. Iwaski et al. (47) showed same observations on fracrionation of zinc in greenhouse soils.

Distribution of Total Zn, Cu, Fe and Mn in Different Cropping Systems

In all the cropping systems, total Zn, Cu, Fe and Mn content varied from 26.5 to 38.0 mg/kg, 1.4 to 3.60 mg/kg, 1.22 to 1.86% and 243.5 to 292.0 mg/kg respectively with mean of 30.31 mg/kg, 2.04 mg/kg. 1.54% and 272.04 mg/kg respectively (Table 5). The higher content of total Zn, Fe and Mn was reported in groundnut-*toria+gobhi sarson* cropping system may also be associated with more replenishment as compared with other cropping systems where their depletion rate is faster. Some of the cropping systems viz. rice-wheat, maize-wheat, maize-potato-mungbean and maize-potato-onion reported lower content of total Zn, Cu, Fe and Mn which may be attributed due to low OC content. In maize based cropping systems, the total Zn, Cu, Fe and Mn ranged from 26.5—28.00 mg/kg, 1.4—1.8 mg/kg, 1.50—1.52% and 254.0—279.5 mg/kg respectively. Agbenin and Henningsen (28) reported distribution of total Zn, Cu, Fe and Mn and their availability and plant uptake of micronutrients under long-term maize-wheat cropping sequence indicated residual micronutrients as the dominant portion of total Zn, Cu, Fe and Mn. Similar results were reported by Behera et al. (29) who reported the distribution of total Zn fraction and their contribution towards availability and plant uptake of zinc under long-term maize-wheat cropping in an *Inceptisol.* Kulandaivel et al. (48) observed the effect of levels of Zn and Fe and their chelation on yield and soil micronutrient status in hybrid rice-wheat cropping system. Kumar and Yadav (11) showed same results with continuous cropping and fertilization on nutrient availability and productivity of an alluvial soil. Patel et al. (49) reported response of groundnut to FYM, sulfur and micronutrients and their residual effect on wheat. Verma et al. (14) reported the effect of decade long fertilizer and manure application on soil fertility and productivity of rice-wheat system in a *Mollisol.* However, Munoz and Beer (50) and Sharma et al. (31) reported that the decrease in total Zn, Fe and Mn after the harvest of wheat which could be due to an increase in the water soluble and exchangeable fractions and held on inorganic sites.

Conclusion

Rice-wheat cropping system is nutrient exhaustive system and is less sustainable as pH, EC and OC in this system decreased with time. Low content of OC in rice-wheat system implies that rice-wheat is more nutrient exhaustive cropping system which depletes OC, available N, P and K. On the other hand inclusion of mungbean, toria, sarson and groundnut in the main cropping system improved the OC, available N, P and K as compared with rice-wheat system. Compared with other systems, DTPA-Zn, Cu, Fe and Mn in rice-wheat system reported their higher levels. DTPA-Zn in rice-wheat system reported higher content which was associated with application of Zn (62.5 kg/ha $ZnSO_4.7H_2O$ annually) fertilizer. The second major reason for higher levels of DTPA-Zn, Cu, Fe and Mn in rice-wheat system is due to permanent reduced conditions during rice cultivation which is not possible in other cropping systems. However, total Zn, Cu, Fe and Mn in different cropping systems didn't follow any definite trend. Only groundnut-toria + gobhi sarson (T_9) cropping system reported higher levels of total Zn, Fe and Mn followed by cotton-African sarson (T_7) cropping system. The higher content of total Zn, Cu, Fe and Mn in this cropping system is attributed to less depletion and more replenishment as compared with rice-wheat system where their depletion rate is faster.

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